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APPENDIX H

STANDARD OUTPUT FORMAT

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H.1 Introduction

As GPS receivers meeting this MOPS are certified for primary means of navigation, it is anticipated that the GPS/WAAS position output will be made available for other on-board and external applications. On-board examples include: ground navigation moving map displays, cockpit displays of traffic information, and weather mapping systems. Users of GPS position which are external to the aircraft include: Traffic Alert and Collision Avoidance System (TCAS) [e.g., RTCA/DO-185], Automatic Dependent Surveillance (ADS) [e.g., RTCA/DO-212], and Automatic Dependent Surveillance - Broadcast (ADS-B) [RTCA/SC-186]. It is important that the GPS position outputs sent to these applications convey the accuracy and integrity provided by the certified GPS receiver. This appendix therefore recommends a minimum output standard for GPS/WAAS equipment which will be able to provide reliable position data to these applications.

Particularly for external applications used to separate aircraft, it is essential that there be no ambiguity in comparing aircraft positions and velocities. For this reason, not only the aircraft position but its time of applicability must meet a common definition.

H.2 GPS Minimum Output and Output Timing

This section describes the recommended minimum output as well as output timing.

H.2.1 Minimum GPS/WAAS Output

The GPS/WAAS equipment outputs recommended here are based on the data items specified in the ADS MOPS (RTCA/DO-212) as well as the industry standards (e.g., ARINC 743A). The parameters listed in Table H-1 represent a minimum set of parameters that should be available from GPS/WAAS equipment meeting this MOPS. Clearly, additional data may be provided and provisions to request specific data at various rates may be desirable options. While the intent is not to require a specific output interface, it is recommended that industry standards (e.g., ARINC 743A, 429) be adhered to in the interest of avionics interoperability.

Table H-1 summarizes key characteristics of the twelve basic parameters that are recommended for a minimum GPS output. The first column is provided for reference to the ARINC 743A field labels used to identify each parameter as it is

output on the ARINC 429 output bus. The output formats are typically two's complement binary numbers (BNR) except for the date which is in binary coded decimal (BCD). The units for each parameter are listed. The positive sense is indicated but many are magnitudes only. The range or maximum is given for each variable. The size in bytes and number of significant bits (excluding sign) are also shown. The resolution of the least significant bit is given for the number of significant bits shown, though some implementations may provide greater accuracy. As can be seen in Table H-1, the total minimum output recommended consists of 34 bytes of data.

TABLE H-1 MINIMUM GPS OUTPUT

743A Label	Parameter	Fmt	Units	pos+	Range**	Sig Bits	Resolut. LSB
110, 120	GPS Latitude*	BNR	degrees	N	" 180	31	8.38E-8
111, 121	GPS Longitude*	BNR	degrees	E	" 180	31	8.38E-8
247	Horiz. Figure of Merit	BNR	nm	***	16	15	4.88E-4
130	Horiz. Protection Level	BNR	nm	***	16	15	4.88E-4
076	GPS Altitude	BNR	ft	up	" 131,072	20	0.125
136	Vert. Figure of Merit	BNR	ft	***	32,768	15	1.0
133	Vertical Protection Level	BNR	ft	***	32,768	15	1.0
103	GPS True Track Angle	BNR	degrees	cw-N	" 180	15	0.0055
112	GPS Ground Speed	BNR	knots	***	4,096	15	0.125
165	Vertical GPS Velocity	BNR	ft/min	up	" 32,768	15	1.0
150,140	Time (UTC, UTC Fine)	BNR	seconds	***	86,400	31	61.035µs
260	Date	BCD	ddmmyy	***	N/A	6	1 day

*** Always Positive

** When no value is available or the value is invalid, the default will be all "ones".

* When either latitude or longitude for a position are invalid, both set to -180E.

The resolution of the least significant bit for latitude and longitude is 8.38E-8, which is less than 9.4 centimeters. This should be sufficient accuracy for even the most accurate modes of operation. The GPS altitude field gives the geodetic height above the WGS-84 ellipsoid and is not corrected for geoidal or barometric variations.

The Horizontal and Vertical Figure of Merit are the current assessment of the 95% accuracy (i.e., 2drms) of the reported position in these dimensions. The Horizontal and Vertical Protection Levels are the current assessment of the 10^{-7} integrity bound

on the reported position in each dimension. It is recognized that the GPS solution may incorporate various levels of augmentation from sources such as inertial navigation, altitude aiding, clock coasting, the Wide Area Augmentation System (WAAS) or the Local Area Augmentation System (LAAS). In each case the equipment is expected to assess its accuracy (i.e., Figure of Merit) as well as its integrity (i.e., Protection Level) in both the horizontal and vertical dimensions. Reporting these parameters should, therefore, replace the need for discrete information about the equipment configuration or status. These parameters are expected to be valid at the time of the report and any delay in recognizing a change in them should be commensurate with the required integrity warning time for that mode.

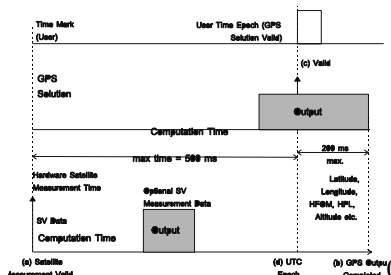
The GPS True Track Angle is the bearing from true north of the velocity vector of the aircraft's GPS antenna. Likewise, the GPS Ground Speed is the speed of the GPS antenna relative to the ground. Vertical Velocity is a signed binary integer in units of feet per minute.

The time parameter is the UTC (universal coordinated time) time of day in seconds. The time of day (contained in the first 17 bits) advances to 86,399 and then starts over at zero. The remainder of the field (14 bits) allow time to be specified to a precision of 61 μ s. The interpretation of the time field is discussed under Section H.2.2. Finally, the date is given in three two-digit BCD fields of day, month, and year.

H.2.2 Timing

In producing an output of GPS position there are four times of interest: a) the time the measurement is made, b) the time the output is available to external applications, c) the time for which the position solution is valid (i.e., User Time Epoch), and d) the UTC Epoch (i.e., the start of a new UTC second). [Figure H-1](#) depicts these events with the lower line representing the measurement of the satellite (SV) data by the tracking loops in the GPS receiver signal processor. Once the measurement has been made, the receiver's data processor can compute a solution including the correction for the receiver clock bias as depicted on the middle line. This solution is computed to be valid at the User Time Epoch which in general may differ from the UTC Epoch. In most GPS receivers (e.g., ARINC 743A) the receiver hardware also generates a pulse at the User Time Epoch as shown on the top line. In some receivers this time pulse is also aligned with the UTC epoch. The actual output of the GPS parameters may precede this time. It is desirable that the time between the measurement and the time of output be as small as possible so that the position can be used before the estimate gets stale.

FIGURE H-1 GPS TIMING RELATIONSHIPS



In addition to the above, there is a very good reason for asking that the time of validity (User Time Epoch) be made as close to the UTC Epoch as possible. When external users such as Air Traffic surveillance or TCAS units on other aircraft want to compute the distance between aircraft, they need to compute positions at a common time such as the UTC Epoch. In order to minimize the extrapolation errors, it is desirable to have the GPS output time and valid time (User Time Epoch) as close to the UTC Epoch as possible. It is therefore recommended that the User Time Epoch be aligned with the UTC Epoch as close as possible. This will have the benefit of not only reducing the extrapolation and latency errors, but will also cause the lower order time bits to be zero. If the receiver is unable to align the User Time Epoch and the UTC Epoch then the external application would have to extrapolate the solution to the nearest UTC Epoch using the velocity data, with the attendant degradation in position accuracy.

In order to keep the total time between the SV measurement and the GPS output/User/UTC Time Epoch as short as possible it is desirable that the time required for the GPS output to take place be small. Typical output data rates (e.g., ARINC 429) are 100,000 bps. Thus it takes only 5.1 ms to output fifteen ARINC 429 data words, which is not very significant compared to the total time available.

It is required that the GPS output period be once per UTC second (Section 2.1.2.6.1). Options for higher rates may be desirable, particularly for applications involving the approach phase of flight (Section 2.1.4.6.1).

H.3 Other Desirable GPS Outputs

The above basic set of parameters is a recommended minimum which will assure that the GPS set provides at least a minimal level of interoperability with other avionics applications. In addition to this basic data, some applications (e.g., inertial navigation system) may need to have access to the underlying satellite measurements (e.g., ARINC 743A). Class Gamma equipment, containing a

navigator, may perform flight following functions analogous to a flight management system (FMS). In this case, data normally provided by the FMS (e.g., ARINC 702, 704, 738) may optionally be provided by the GPS set. This data may include waypoints on the planned flight path as used in the ADS Predicted Route Group (RTCA/DO-212).

H.4

Summary

This appendix recommends that basic GPS outputs be provided for use by on-board and external systems. Basic position and velocity data should be provided with a one second period aligned to the UTC Epoch. Associated accuracy and integrity assessments will allow the position data to be properly used regardless of the details of the equipment configuration or mode of operation.